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ABSTRACT

This study is an evaluation one phase of the Biology Critical Thinking (BCT) project. Seven skills were selected as goals of the BCT project (for example, isolating variables) and learning activities for these skills were developed. The study compared two groups using the same textbook (n=678 Israeli seventh grade students). The following instruments were used: General Skills Test (GST); the Biological Skills Test (BST); and a Concepts Test of the topic "water balance in living organisms." Cronbach alpha reliability for the GST was 0.62 and for the BST was 0.63. Results indicate there were significant differences between the posttest scores of the two groups for the GST and the BST. The effect sizes were large (E.S.=2.0 and 2.5). (PR)

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Developing Critical Thinking: A Useful Instructional Strategy for Promoting In Depth Science Learning

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Objectives

This paper describes stage 2 of the Biology Critical Thinking (BCT) project. Activities which were carefully desighned to develop specific critical thinking skills are incorporated into the regular school curriculum and used as a routine. The present paper describes a wide-scale study focusing on water balance in living organisms. The rationale and activities of a BCT pilot project were described elsewhere (Zohar & Tamir, in press). More specifically, the purpose of the study was to find out whether (and to what extent) the teaching strategies used in the BCT project can:

1) contribute to the development of critical thinking skills in various biological topics.

2) contribute to the transfer of critical thinking skills to other (non biology) subject -matters.

3) Influence the students' biological knowledge.

4)influence classroom learning environment.

Theoretical Framework

Lately we are witnesses to numerous educational endeavors to foster the development of reasoning skills. One of the approaches common to such endeavors is the "infusion" approach , in which the development of thinking is infused within regular disciplinary courses (Mcpeck, 1981; Ennis, 1989). This approach is rooted in the notion that general and domain-specific cognitive skills seem to interact in human cognition (see Perkins & Salomon, 1989, for review). Thinking strategies are strongly dependent upon one's existing theories and concepts (Kuhn et. al., 1988; Kuhn, 1989). This viewpoint calls for teaching thinking skills within a knowledge- rich environment. Infusing the teaching of thinking skills in regular disciplinary courses may provide such an environment.

One common claim against the infusion approach concerns the issue of transfer: If thinking skills cannot transfer from one content domain to another, it seems inefficient to teach them in a specific field since this will not contribute to students' performance in other fields. However, recent studies indicate that under certain

learning conditions, transfer of thinking skills can take place. Among these conditions are exposure to multiple examples in different content areas and supplementing the examples by rules and generalizations- particularly when the latter are formulated by the learners themselves (Gick & Holyoak, 1987; Lehman, Lampert & Nisbet, 1988; Brown, Kane & Long, 1989).

Method

a. General description

Seven skills were selected as goals of the BCT project (for example:

Identifying explicit and hidden assumptions, or isolating variables).

Learning activities combining these skills with specific biology topics were developed. Each of the seven skills was repeated (in the various content areas) 6-9 times.

The BCT project followed several guidelines:

1. In order to enhance transfer the same skill was repeated in several occasions and in a variety of contexts. Based on the students' concrete experiences with the same reasoning pattern in different contents, the students generalized rules concerning that particular reasoning pattern. Application of the reasoning skill in everyday life was discussed.

2. The time devoted to the activities was reasonably short, so that other instructional goals were not deprived.

3. The activities included group and class discussions, problem solving and analysis of experiments and data.

The study consisted of two groups which studied the same textbook. The control group studied the unit in a conventional manner. The experimental group carried out the BCT activities in addition to the regular program.

b. Instrumentation

The BCT activities were assessed by several instruments:

1. Two parallel forms, developed by the authors for the general skills test. (GST). This test evaluates

performance in the seven critical thinking skills mentioned above. In composing the test, items and ideas from several sources were included (e.g. Jungwirth, 1985; Tamir, 1988). The tasks in these tests are similar in their logical structure to the BCT learning activities, but deal with different and unfamiliar topics (general as well as biological). The test does not require prior knowledge. One form was used as a pretest and the other as a post test.

2.The biological skills test (BST) has a similar logical pattern as the GST. The difference between the two tests is that the BST requires prior biological knowledge.

3. A concepts test (CT) of the topic "water balance in living organisms". The items in this test were taken from a test designed by the authors of the textbook.

4. A follow-up of teachers' feedback was carried out through teachers' weekly reports, following the Self Lesson Report Form (SLRF) developed and validated by Tamir (1983).

c. Validation of tests

GST & BST were examined by three experts who approved their content validity. The tests were piloted twice, each time with approximately 70 students. The results were used to revise the tests, and to create two sets of GST items that would be equivalent in their level of difficulty. One of the sets was used as the pretest and the other as the post test.

α Cronbach reliability (internal consistency) indices were 0.62 and 0.63 for the GST and BST respectively. These values are high enough for purposes of group comparisons. Critical thinking tests generally have lower reliabilities than intelligence tests. Reliabilities estimates tend to range from about .65 to .75 and tend to increase with the level of sophistication of examinees (Norris & Ennis, 1989). One way to increase the reliability is to make the test larger. A combined score of the two tests will be significantly more reliable (using the Spearman Brown formula r will increase from .62 to .77).

Data source

678 seventh grade students (ages 12-13), 340 boys and 338 girls participated in the study. The experimental students (n=367) studied in 11 classes in 4 schools, whereas the control students (n=311) studied in 10 classes in 4 different schools. All these schools were similar both in terms of students' socio-economic background and in terms of teachers' education and experience (Hen & Edri, 1989)

Results and conclusions

A comparison between the experimental (e) and control (c) groups show that the pretest mean scores of the two groups were practically the same ($\bar{x}e=41.6$; $\bar{x}c=41.3$), indicating that the two groups did not differ in their initial performance. However, in the post test a big difference was observed between the two groups: The mean scores in the general skills post test were $\bar{x}e=78.7$; $\bar{x}c=46.5$. This difference is statistically significant ($t=17.6$; $P<0.001$) and the effect size is very large (E.S= 2.0). While the biological skills test was more difficult for students in both groups ($\bar{x}e=72.9$; $\bar{x}c=29.3$), the difference between the two groups was found to be even larger (E.S= 2.5). Comparison within groups between pre and post tests indicates a large gain in the experimental group ($\bar{x}pre=36.7$; $\bar{x}post=78.2$; $t=25.0$; $P<0.001$). These results show that the students who participated in the BCT project improved their critical thinking skills compared to their own initial level and compared to their counterparts in the control group.

Improved critical thinking skills were observed in a new biological context, as well as in non-biological, everyday topics. Under the learning conditions specified in the study, thinking skills that were taught in a rich biological content domain, transferred to other content domains. This finding contributes to the ongoing debate obout transfer, indicating that transfer of thinking skills can indeed take place.

Although some of the teaching time in the present study was taken by the BCT activities, the experimental group's mastery of the topic "water balance in leaving organisms (measured by the concepts test) was better than the control's ($\bar{x}e=86.9$; $\bar{x}c=73.8$; $t=25.04$; $p<0.01$). Similar results were obtained in previous studies

that integrated the teaching of scientific thinking skills with the teaching of scientific topics (Moll & Allen, 1982; Crow & Haws, 1985; Self Et. al., 1989). This suggests that the infusion of critical thinking skills to a curriculum as described in this study, need not create a conflict between "knowledge" of facts as one educational goal and learning to think as another. Rather, these two goals seem to interact: Thinking critically about specific topics implies higher-order thinking about these topics. This results in less rote and more meaningful learning that leads to improved understanding and better retention of facts (e.g Tamir & Jungwirth 1975).

Analysis of the teachers' self lessons report indicated that the BCT involvement decreased the frequency of teacher-centered teaching and enhanced student-centered more active learning: an increase in class and group discussions as well as in laboratory, inquiry oriented work was observed. This change might have contributed to the better performance of the experimental group scores in the concept test. This change is especially appropriate for the teaching of thinking. Recent studies suggest that instructional activities that take place in a social setting, provide occasions for modeling effective thinking strategies (Resnick & Klopfer, 1989; Brown & Campione, 1990).

Educational importance

This study indicates that a belief in the importance of teaching thinking skills, combined with a repertoire of learning activities matched to different topics is a fruitful approach for enhancing thinking skills and for transfer. If several school subjects would be taught using a similar approach, so that students will encounter a variety of thinking skills in varied contexts, the present study provides evidence which supports the hope that they will indeed become "better thinkers".